THE EFFECTS OF FOREST FERTILISATION ON THE ABUNDANCE AND DIVERSITY OF ECTOMYCORRHIZAL FUNGI.

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During the last few years of research on the effects of air pollution on forest vitality, the importance of nitrogenous compounds as a cause of forest dieback became increasingly clear (Nihlgaard, 1985).However, hypotheses based on the effects of acidifying substances and this ammonium-hypothesis are of course not mutually exclusive and it is usually difficult to discriminate between these hypotheses on the basis of field observations and field experiments.

In this contribution I would like to discuss some field experiments with forest fertilisation (and the removal of nutrients by sod-cutting) in order to show how these processes can be interlinked.

The first experiment is a field trial in a 25-year old forest of Scots pine (Pinus sylvestris L.) on an acid sandy soil with a pH of about 4.0 in Harderwijk (central part of the Netherlands). Within this rather homogeneous stand, 72 plots, each measuring 12m x 15 m = 180 m^2, have been subjected to three different fertilisation treatments and investigated regularly. The first experiment is a so-called factorial experiment, where potassium, magnesium, calcium, and phosphorus are applied separately and in all possible combinations. This experiment should give an answer to the question whether the excess of nitrogenous compounds can be more effectively used with the addition of the other elements that are otherwise in short supply.

The second experiment is a liming experiment where calcium carbonate (in quantities ranging from 3T/ha to 18T/ha) is applied, with additional fertilisation with potassium, magnesium, and phosphorus. This experiment should give an answer to the question how useful the application of lime is in order to over come acidification per se.

Finally an experiment with liquid manure is carried out. This experiment is mainly done for political reasons.

Results of the mycological investigations after two years will be published shortly (Kuyper & de Vries, 1988). In this contribution I will only summarise the effects of calcium in the first and second experiment (Table 1).

Table 1. Effect of applying calcium.

	with Ca (n = 36)	without lime (n = 27)
Total number of ECM species	8	13
Average number of ECM species/plot	1.1	2.5 **
Average number of ECM specimens/plot	4.2	6.6 **
Laccaria spp.	6%	48% **
Lactarius hepaticus	47%	89% *
Xerocomus badius	11%	26%
Paxillus involutus	25%	26%
Average number of saprophytic spp./plot	6.3	9.6 **

* significant at $p < 0.05$; ** significant at $p < 0.01$.

In all 13 species of ectomycorrhizal fungi were present in the plots that were not treated with lime, but only 8 species were found in the limed plots. No species were unique for this latter treatment. The average number of species per plot (2.5 in the unlimed plots, 1.1 in the limed plots) is highly significant between both treatments. Species of the genus Laccaria (L. proxima and L. bicolor) and Lactarius hepaticus are significantly more common in the unlimed plots. Only Paxillus involutus seems unaffected by lime.

If we substitute these qualitative data for quantitative ones (number of specimens) the same picture emerges. We can therefore conclude that there is only a small additional effect of species abundances.

Negative effects of liming on ectomycorrhizal species have been noted before. Hora (1959) found that liming in a stand of Scots pine had a depressing effect on the abundance of Paxillus involutus and Lactarius rufus. Fiedler & Hunger (1963) studied the effects of liming on the mycoflora of a Norway spruce forest (Picea abies (L.) P. Karst.). Nine years after the application of lime or dolomite they noted a clear decrease in productivity and a (very) small decrease in species diversity of ectomycorrhizal fungi.

Fiedler & Hunger did not explain this depressing effect of lime, but their discussion makes implicit that they consider a shift towards increased productivity and diversity of saprotrophic species as the main determinant of this effect. Pierart (pers. comm.) also considers it likely that sporocarp

formation by saprotrophic fungi exerts a negative influence on that of symbionts. A pH effect was said to be only relevant after an increase in pH to above 6.5. pH measurements in Harderwijk indicate a rise after liming of about 2 units to 6.0, thus below the value given by Fiedler & Hunger. Their first explanation is even less likely , considering the significant decline in species diversity and productivity of saprotrophic species after liming (Table 1).

I would suggest that this decrease of ectomycorrhizal fungi after liming is not a direct effect of calcium, but reflects the increased availability of mineral nitrogen (both ammonium-N and nitrate-N) with its harmful effects on mycorrhiza (Meyer, this symposium).

Support for this hypothesis can be obtained from results from investigations made by my colleague de Vries in several pine woods in the northern part of the Netherlands (Appelscha, Smilde, Dwingeloo). De Vries studied the effects of both liming and sod-cutting, the removal of the litter- and humus-layer (Table 2). The plots have been limed with 1T calcium carbonate/ha. By sod-cutting a large part of the pine roots are also removed, because only a small part of the fine roots are initially present in the mineral layer, but after three years they will certainly have increased.

Table 2. Effect of sod-cutting and liming on diversity of ecto-mycorrhizal species (number of species/plot).

	with lime	without lime
control	4.3	5.3
sod-cutting	7.7	7.7

A negative effect of liming in the presence of a litter layer can again be noted, but this effect is not significant (probably also caused by much smaller sample size than in the first experiment). There seems to be no effect of calcium when the litter layer is removed. Differences between sod-cutting and the controls are on the other hand statistically significant ($p < 0.05$). Substituting these qualitative data for quantitative ones yields some difficulties, because species of <u>Laccaria</u> are very numerous in some plots (irrespective of treatment) and (almost) lacking in others. These differences in abundance of <u>Laccaria</u> species are so great as to influence the analysis completely. The analysis, when done without <u>Laccaria</u>, is consistent with the picture based on qualitative data.

These results support the hypothesis that there is not so much a calcium effect per se, but an indirect effect of calcium by increasing the availability of mineral nitrogen. The decrease of

ectomycorrhizal species after liming is in fact a nitrogen effect (Meyer, this symposium; Termorshuizen, this symposium).

If this hypothesis is correct, it has some important implications. Liming in the presence of a litter layer has a depressing effect on diversity and abundance of ectomycorrhizal species. However, the increasing thickness of the litter layer itself, as can be observed in stands in the Netherlands, might also be due to nitrogen pollution. We should therefore investigate effects of the litter layer in depressing ectomycorrhizal species. The hypothesis, forwarded by Gadgil & Gadgil (1975) about the inhibitory effects of ectomycorrhizal species on litter decomposition might be invalid in litter with a high N-content. Besides direct effects of mineral nitrogen, indirect effects by recalcitrant substances in the litter layer might well play such a depressing role.

Literature

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